wireless power transmission. If a metal object is present, efficiency may be reduced substantially (e.g., from 90% to 40%). Further, due to the power absorbed, the temperature of the object may increase significantly, which may be undesirable. Techniques have been developed for sensing the presence of a foreign object. However, prior techniques for sensing the presence of foreign objects have various disadvantages, including limited detection capability at low power levels, a lengthy detection process which wastes power, and/or the need to add additional circuitry or coils which lead to additional complexity and expense.

[0028] The techniques and devices described herein enable the detection of a foreign object using relatively low power levels. In some embodiments, detection may be performed by energizing and controlling the drive circuit of a wireless power transmitter, and measuring a characteristic of a transient in the wireless power transmitter. Based on the transient characteristic the wireless power transmitter can determine whether a foreign object is present in the field produced by the wireless power transmitter. Advantageously, in some embodiments detection of a foreign object may be performed without the need to add additional hardware.

[0029] FIG. **1** shows a block diagram of a wireless power system **100** including a wireless power transmitter **1** and a wireless power receiver **11**. The wireless power transmitter **1** has a drive circuit **7** including an inverter **3** that drives a transmit coil **10** through a matching network **6**. The wireless power transmitter **1** may include a regulated voltage source **2** (e.g., a voltage regulator) that provides a regulated DC voltage to the inverter **3**. The regulated voltage source **2** produces a regulated DC output voltage in response to control stimulus from the controller **5**. In some embodiments, the drive circuit **7** may be a class D or E amplifier that converts the DC voltage at the input of inverter **3** into an AC output voltage to drive the transmit coil **10**. Producing an AC output voltage enables wireless power transmission through electromagnetic induction. The controller **5** may control a signal generator **9** to drive the inverter **3** with signals of a selected wireless power transmission frequency. As an example, the inverter **3** may be switched at a frequency between 100 and 205 kHz to transmit power to a wireless power receiver designed to receive wireless power according to the Qi specification for low power Qi receivers and 80-300 kHz for medium power Qi receivers. The inverter **3** may be switched at a higher frequency, such as a frequency of greater than 1 MHz, within an ISM band, e.g., 6.765 MHz to 6.795 MHz, to transmit power to a receiver designed to receive wireless power using MR technology. However, these frequencies are described merely by way of example, as wireless power may be transmitted at a variety of suitable frequencies, in accordance with any suitable specification. Controller **5** may be an analog circuit or a digital circuit. Controller **5** may be programmable, and may command signal generator **9** to produce signals at a desired transmission frequency based on stored program instructions, so that inverter **3** switches at the desired transmission frequency. Matching network **6** may facilitate wireless power delivery by presenting a suitable impedance to the inverter **3**. The matching network(s) may have one or more capacitive or inductive elements or any suitable combination of capacitive and inductive elements. Since the transmit coil **10** may have an inductive impedance, in some embodiments the matching network **6** may include one or more capacitive elements, which, when combined with the impedance(s) of the transmit coil **10**, presents an impedance to the output of inverter **3** suitable for driving the transmit coil **10**. In some embodiments, during wireless power transfer the resonant frequency of the matching network **6** may be set equal to or approximately equal to the switching frequency of the inverter **3**. The transmit coil **10** may be realized by any suitable type of conductors. The conductors may be wires, including solid wire or Litz wire, or patterned conductors, such as patterned conductors of a PC board or an integrated circuit.

[0030] The AC current in the transmit coil **10** generates an oscillating magnetic field in accordance with Ampere's law. The oscillating magnetic field induces an AC voltage into a receiver coil **12** of the wireless power receiver **11** in accordance with Faraday's law. The AC voltage induced in the receiver coil **12** is provided through a matching network **13** to a rectifier **14** that generates an unregulated DC voltage. Rectifier **14** may be a synchronous rectifier or may be implemented using diodes. The unregulated DC voltage is regulated using a DC/DC converter **15**, the output of which may be filtered and provided to a load as output voltage Vout. In some alternate embodiments the DC/DC converter **15** can be replaced by a linear regulator or battery charger, or eliminated altogether.

[0031] As shown in FIG. **1**, if a conductive foreign object **20** enters the field produced by the transmit coil **10** of the wireless power transmitter **1**, the wireless power transmission efficiency may be degraded and/or the conductive foreign object **20** may undergo significant heating. Examples of conductive foreign objects **20** include coins, paperclips, keys, by way of illustration.

[0032] According to the techniques described herein, the wireless power transmitter **1** may be controlled to perform foreign object detection prior to wireless power transmission. Performing foreign object detection allows the wireless power transmitter to determine whether or not to perform wireless power transmission.

[0033] Foreign object detection may be performed as follows. When the wireless power transmitter **1** performs foreign object detection it may increase the energy stored in one or more components of the matching network **6** and/or transmit coil **10**. A resonance in matching network **6** and/or transmit coil **10** is excited and allowed to decay. A temporal characteristic of the decay of the resonance is measured. Since the rate of decay of the resonance is different depending on whether or not a foreign object **20** is present, the temporal characteristic of the resonance decay can be analyzed to determine whether or not a foreign object **20** is present. Wireless power transmission can be enabled or inhibited based on this analysis. If a foreign object is determined to be present, wireless power transmission can be disabled. If a foreign object is determined not to be present, wireless power transmission may be enabled.

[0034] FIG. **2** shows a flowchart of a method of performing foreign object detection, according to some embodiments. Such a method may be performed by the wireless power transmitter **1**. Specifically, controller **5** may be configured to control performing the method. In step S**1**, the matching network **6** and/or the transmit coil **10** is energized. Step S**1** may be performed by increasing the energy stored in one or more passive components in the matching network **6** and/or transmit coil **10**. Matching network **6** and/or the transmit coil **10** may be energized by switching inverter **3**